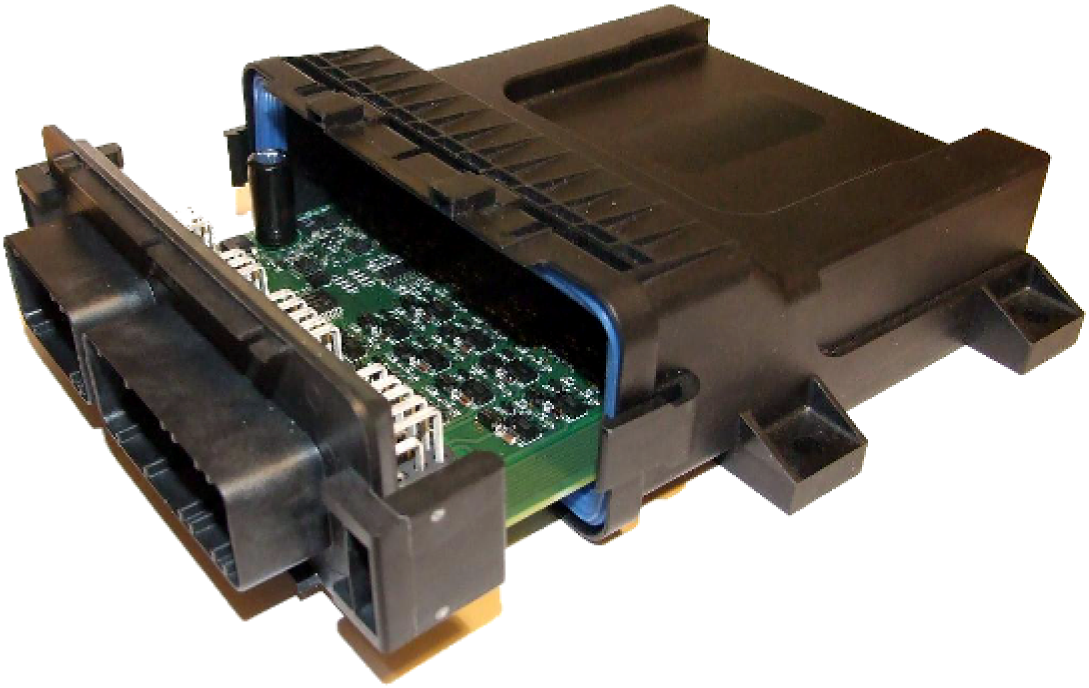
VEGA3 DEVELOPMENT ECU
USER MANUAL



PRELIMINARY DRAFT

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AUTHOR: Mike Evans

Address: Lyra Electroncs Ltd
The Venture Centre
Sir William Lyons Road
Coventry
CV4 7EZ

Web: www.lyraelectronics.com
email: admin@lyraelectronics.com
Phone: 0121 667 9832

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1 INTRODUCTION

The Vega3 Electronic Control Unit (ECU) is a module for developing real-time control applications.

It has been designed for the electric vehicle market, although it can be used in any application that requires a rugged, compact and powerful ECU.

By carefully considering the functional requirements and combining this with a case that is cost effective yet completely waterproof, the Vega3 is rugged, practical, affordable but extremely capable.

ASIL D applications can be considered, due to the two microprocessors from different manufacturers that can self-monitor or monitor each others operation.

Since the module is suitable for high-volume applications, development costs are reduced as the same module can be used to develop the system as will be used in the final application. This has the added benefit of not having to re-code for a production-intent module, and removes the risk of errors being introduced (both software bugs and hardware incompatibilities).

Code once. Demonstrate on a small scale. Deploy on a large scale.

2 HARDWARE

This section describes the Vega3 ECU from an electronics hardware perspective.

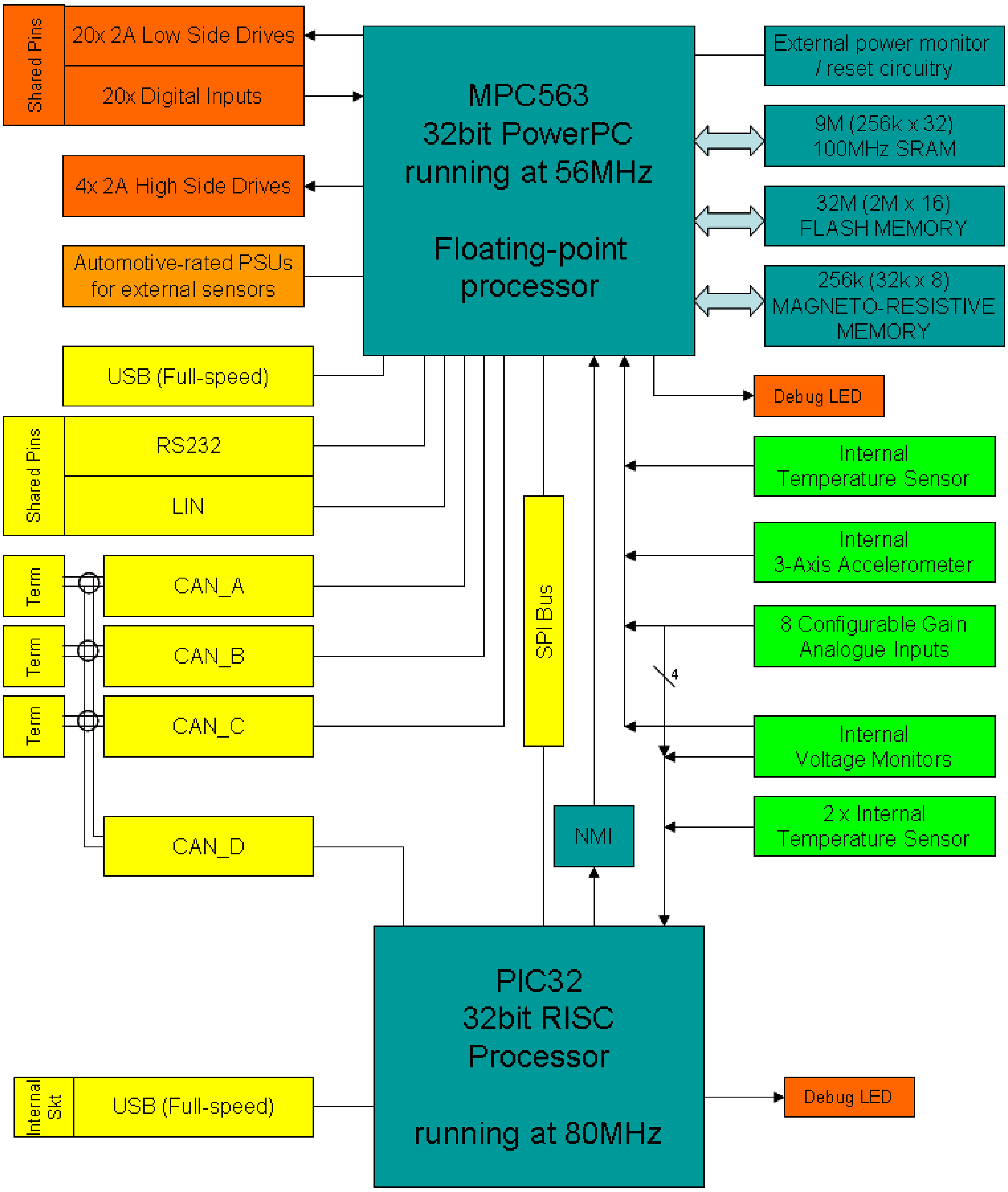
2.1 FUNCTIONAL DESCRIPTION

The Vega3 is a general purpose ECU designed to automotive specifications.

It has two microprocessors, both 32bit high-end specification, with an interconnecting SPI bus and a NMI reset line from the PIC32 to the MPC563. This allows software to be written that complies to an ASIL rating for safety.

Flexible routing of CAN buses allow the PIC32 to monitor / connect to any of the three CAN buses.

Block diagram :



2.2 ABSOLUTE MAXIMUM RATINGS

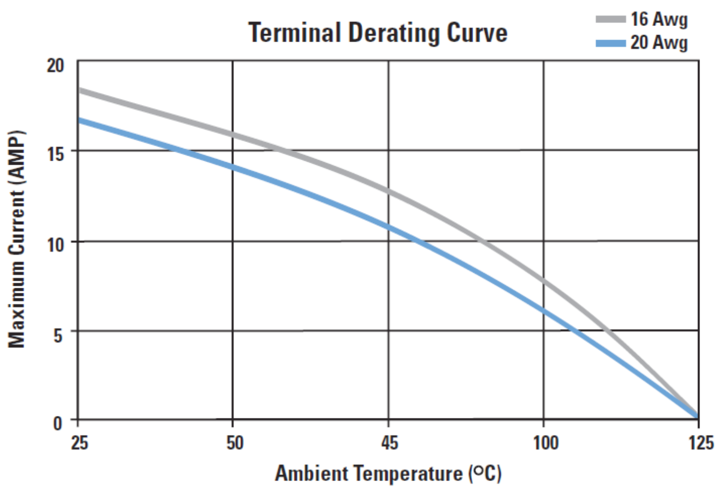
- Maximum supply voltage (beyond which damage may occur): 36V[1]
- Maximum external fuse rating: 20A
- Maximum total high-side load: Limited by Vbat pin rating of 10A
- Maximum total low-side load: Limited by two GND pins total rating of 20A

The Vega3 ECU is protected from over-voltage by a 33V stand-off 5kW transient voltage suppression (TVS) diode. It begins to conduct at 37V, clamping the voltage to the Vega3 and dissipating the over-voltage energy as heat. It is designed to protect against voltage spikes and commonly experienced automotive transient over-voltages, but no device will survive continuous over-voltage. External fusing of the Vega3 is important.

The Vega3 has a reverse-polarity protection circuit, drawing only diode leakage current until correctly connected.

2.2.1 CONNECTOR PIN DE-RATING

The Cinch connector pins are nominally rated at 10A per pin, but this value should be de-rated with increasing temperature.



At the upper limit of the Vega3 temperature range of 85°C, 5A would be a conservative limit. As a comparison, the low side drives can sink a maximum of 3.5A before current limiting.

2.3 HARDWARE SUMMARY

Vega 3 – Electric, Hybrid Vehicle and Marine ECU		
Power Supply	Operating voltage range	7 – 33V DC
	Max. total LSD load	20A (note temperature derating curve)
	Max. total HSD load	10A (note temperature derating curve)
	Nominal operational current	250mA
	Standby quiescent current	4mA
	Shut-down	SW controlled. The MPC563 can hold power on after “Key On” has been released to enable a graceful system shut-down, without an external relay.
Core 1	Microcontroller	Freescale MPC563, supporting double-precision floating point operations.
	Clock Frequency	56MHz
	Internal Flash	512k bytes
	External Flash	32Mbit
	MRAM (EEPROM)	256kbit
	Internal SRAM	32k bytes
	External SRAM	9Mbit 100MHz
Core 2	Microcontroller	PIC32MX
	Clock Frequency	80MHz
	Internal Flash	256k
Inputs	Digital Inputs	20 digital inputs, each individually configurable to be used as switch inputs, sensor logic inputs, or voltage threshold inputs. Automatic independent monitoring of digital outputs. All capable of frequency and timing measurements.
	Switch inputs	
	Frequency Inputs	
	Monitoring digital outputs	
	Analogue Inputs	8 external inputs, 8 from an internal header. 4 x oversampled, 10 bits, single-ended with configurable input divider and gain. 4 of these are also measured by PIC32.
Internal Monitors	Temperature	3 sensors. Internal box temperature measured by MPC563. Output drives and MPC563 temperature measured by PIC32.
	Power supply monitors	Vbat, 5V sensor Supply, Key On voltage and 2v6 supply measured by MPC563. Vbat, sensor 5v, 2v6 independently monitored by PIC32
	Accelerometers	3-axis sensor, with X, Y, Z signals on separate ADC channels

Outputs	Medium Current Drivers (3A)	20 low side drives with PWM capability. 4 high-side drives with PWM capability.
	Sensor Supplies	5V 250mA output, software switchable with ADC measurement of output voltage to detect overloads / shorts.
Communications	CAN 2.0B	3 CAN ports to MPC563 processor + 1 internally selectable to PIC32 processor (4 transceivers).
	USB	Full USB - COM port emulation with FT232R Internal USB mini port from PIC32 (host or device).
	RS232	1 port, pins shared with LIN
	LIN	1 port, pins shared with RS232
Environmental	Operating temperature range	-40 to +85°C
	Construction / IP rating	IP65, IP66, IP67, IP69K
	Connector	18pin + 30 pin Cinch
	Contact resistance	<10mΩ
	Insulation resistance	>1000MΩ
	ESD protection	All pins protected to 4kV human body discharge model, including USB.
	Vibration (case)	10 - 2000 - 10Hz: 15g's
	Shock (case)	20 pulses 50g's
	Salt spray	96 hours
	Temperature Humidity Cycling	320 hours. 40x8hr cycles -40 to 85°C @ 85% RH to 125°C
	Fluid resistance	Most industrial fluids
	ROHS / WEEE requirements	
Physical	Dimensions	
	Material	
	Weight	

2.4 MECHANICAL ASSEMBLY

The Vega3 is supplied with the outer case not mated to the connector, i.e. the PCB can be withdrawn from the housing.

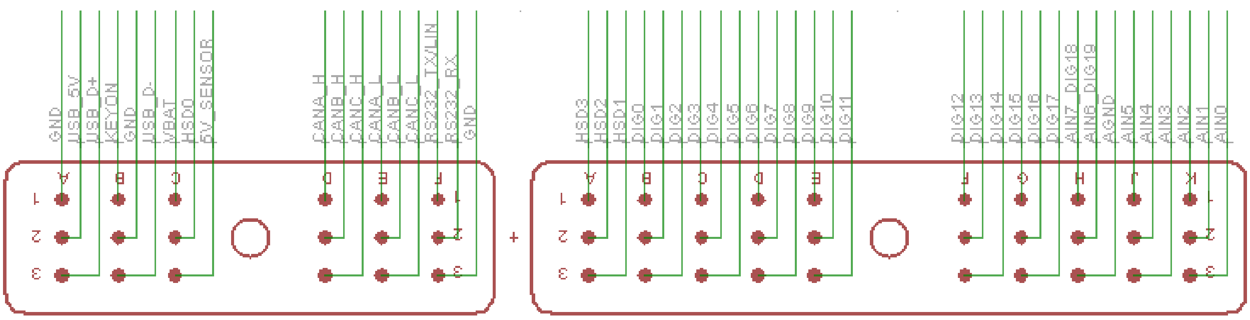
This is to allow for modifications to be made to suit the application (e.g. for pull-up resistors to be added), and to allow the PIC32 processor to be programmed if required.

Since the assembled Vega3 unit is completely waterproof once the connector is mated with the outer case, a special tool is required to separate them again. The release tool is Cinch part 5991111611. In an emergency, the case can be separated by using many small screwdrivers inserted into key points, but it is easy to damage the plastic locking points and ruin the seal. The Cinch tool is recommended.

Details of the Cinch case, mating connectors, crimps and tools can be found at:
http://www.cinch.com/products/modular-integrated-connector-enclosure/modice-se-le

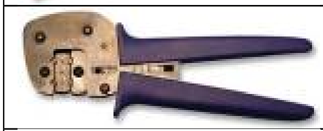
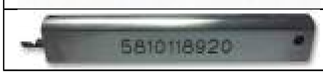
These parts are stocked by most major electronics distributors (RS, Farnell, Digikey etc.)

2.5 PINOUT



2.6 ACCESSORIES

The full list of Cinch parts are listed below, together with part numbers for popular suppliers. Not all of these parts may be needed – it is possible to use the Vega3 as a CAN gateway for instance with only the one 18 way connector. Although both crimp sizes and tools are listed, the smaller 0.5 to 0.8mm^2 wire should be suitable for most applications of the Vega3.

Image	Description	Cinch Part	RS Part*	Farnell Part*
	18 way mating connector	5810118023	664-7254	1282205
	30 way mating connector (alternate keyway)	5810130029	664-7267	1282208
	Crimp terminal for 0.5-0.8mm^2 wire (20 to 18 AWG)	4250000872	664-7260	1282209
	Crimp terminal for 0.8-1.0mm^2 wire (18 to 16 AWG)	4250000873	664-7264	1282210
	Sealing plug for unused crimp positions.	5810000011	664-7295	1282218
	Crimp tool for 0.5-0.8mm^2 terminals (20 to 18 AWG)	5991111615	664-7273	1282211
	Crimp tool for 0.8-1.0mm^2 terminals (18 to 16 AWG)	5991111616	664-7276	1282213
	Cinch case disassembly tool	5991111611	664-7282	1282216
	Crimp removal tool	5810118920	664-7270	1282214

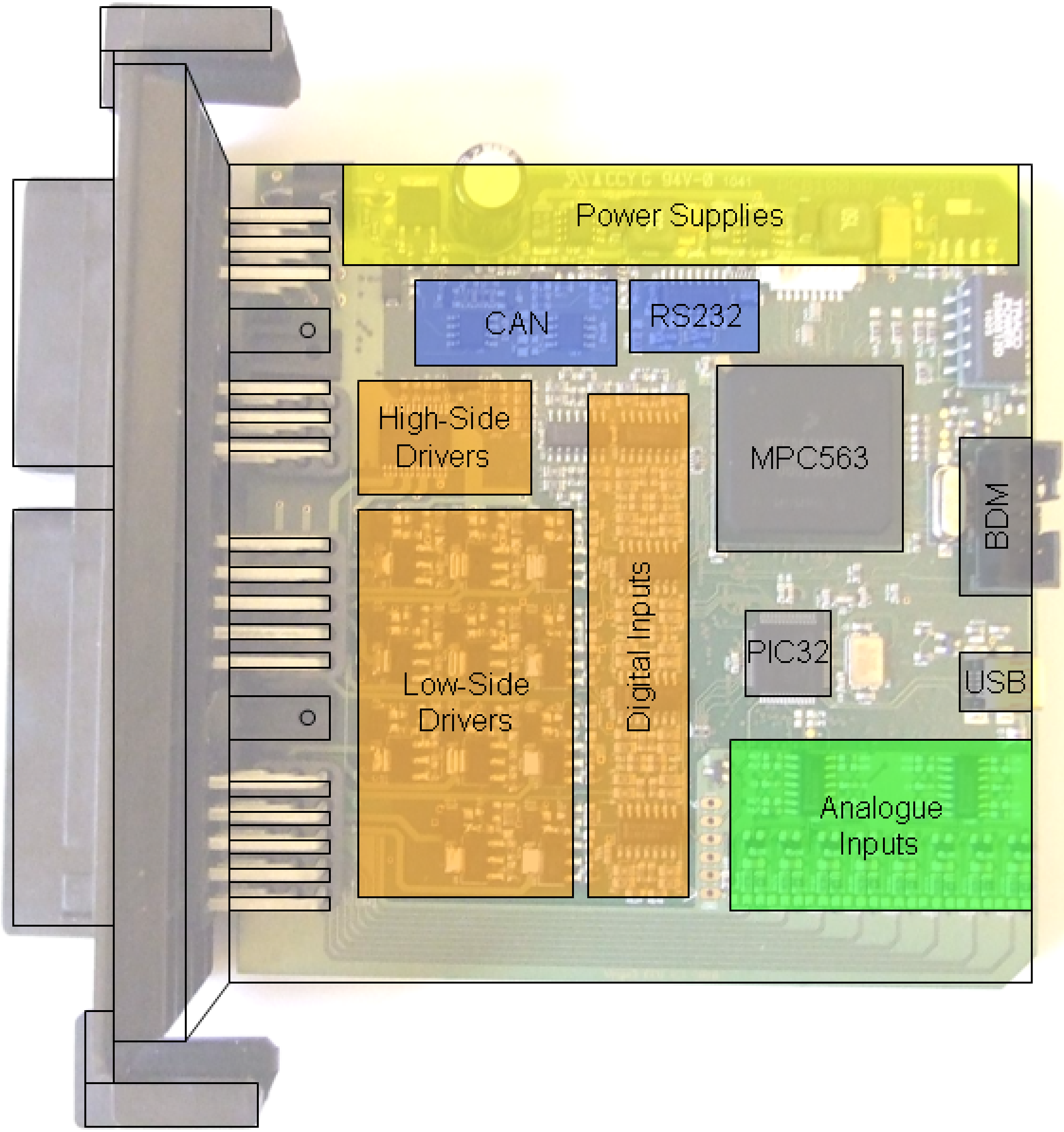
* The supplier part numbers are correct at the time of issue of this document, but may change.

2.7 OVERVIEW OF PCB

The PCB is designed to be customisable by the end user. All pull-up, pull-down, gain and hysteresis components are the larger “0805” size surface mount components to simplify rework. Most of these components are on the top side of the board for the same reason.

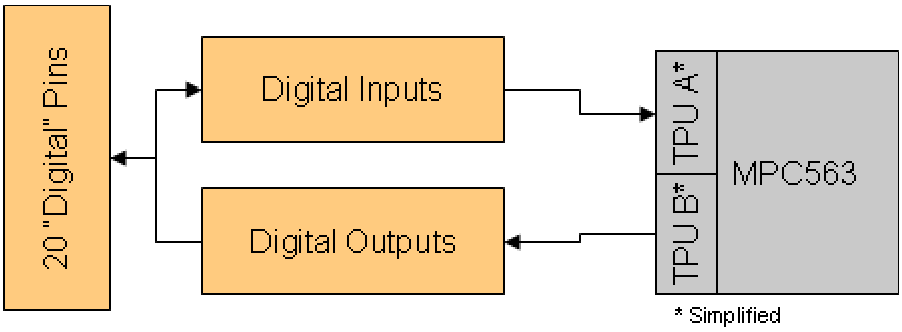
Spice simulations are provided of the customisable interfaces to verify the intended operation before changing real components – please see the “LTSpice Simulations” folder on the installation disk.

The top side of the board is arranged like this:



2.8 DIGITAL INPUTS AND OUTPUTS

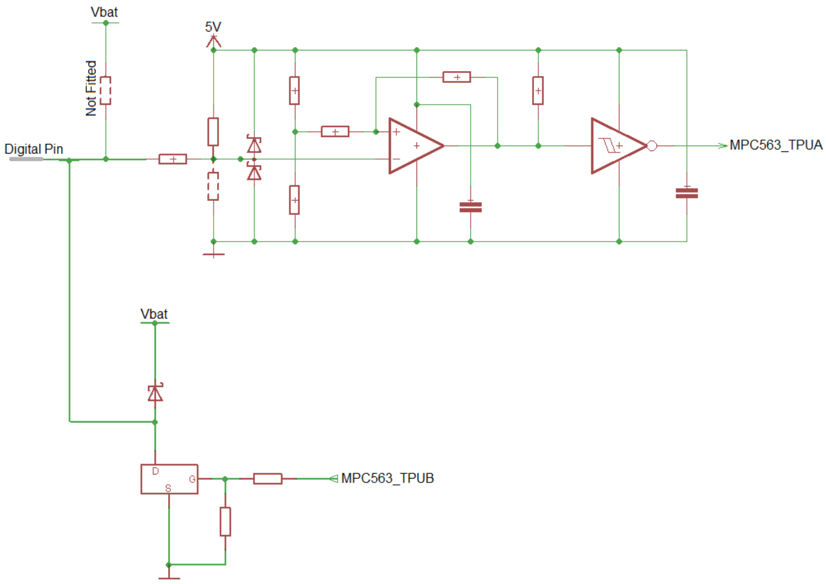
There are 20 pins on the Vega3 that are shared between digital inputs and digital outputs, although they are distinctly separate to the processor.



The 20 digital outputs are permanently connected to the 20 digital inputs at the connector pins. This allows independent monitoring of the state of any driven digital outputs.

If a digital pin is required to be an input, the digital output should not be driven. Be aware that the digital output protection diode (shown below) may affect readings if the input is floating (i.e. with no pull-ups or weak pull-downs) due to the unavoidable small leakage current through this diode.

It is recommended that digital inputs are 'pulled high and switched to ground' where possible.



The last two digital I/O pins (DIG18 and DIG19) are further shared with analogue inputs 6 and 7, which also have provision for pull-up and pull-down resistors.

2.9 DIGITAL INPUTS

At their simplest, the Vega3 digital inputs are used to detect when external devices (e.g. switches) are on or off, or to measure a frequency (or period) that an input is oscillating at.

2.9.1 HARDWARE

There are 20 digital input circuits, each identical to the one shown below.

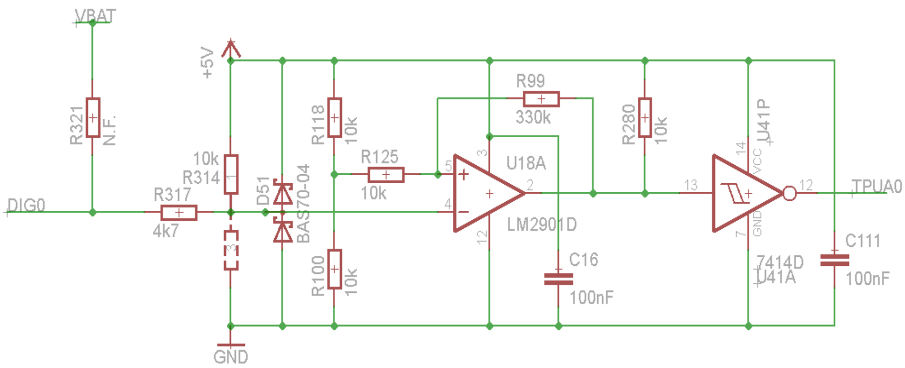
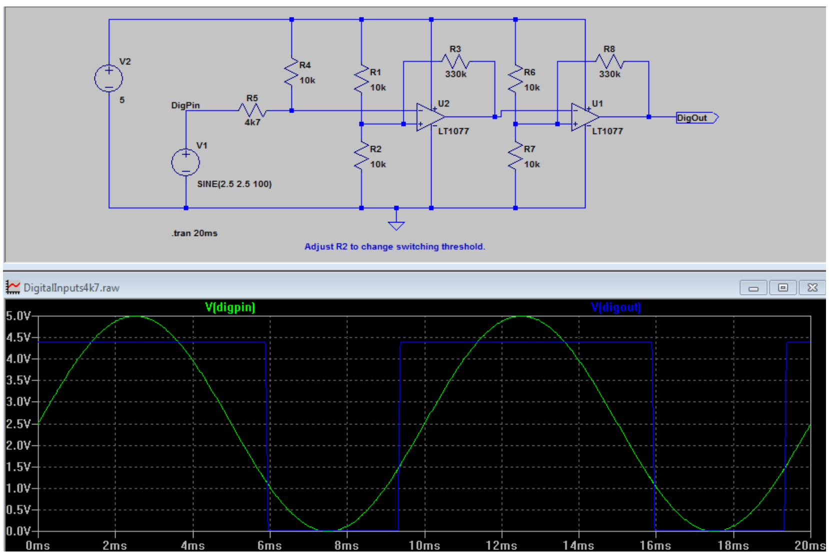


Figure 1: Digital Input Schematic

For Dig0 shown above, the threshold voltage at which the digital input switches from 1 to 0 can be set by adjusting R118 and R100 (designators will be different for each channel). R314 and R317 can be used as a potential divider if larger input voltages are to be used, with R314 moved to its pull-down position.

To prevent oscillations as slowly-moving inputs pass through the trigger level, positive feedback is introduced with R99. This resistor can be changed to vary the amount of hysteresis.

The supplied LTSpice simulation shows that the default switching threshold is around 1.5V.



2.9.2 MPC563 DIGITAL INPUTS ASSIGNMENT

Each channel of the digital input circuitry is connected to a unique MPC563 pin, given below.

Generally they map to TPUA channels, but since there are only 16 channels per TPU, the last four digital inputs are connected to TPUB inputs.

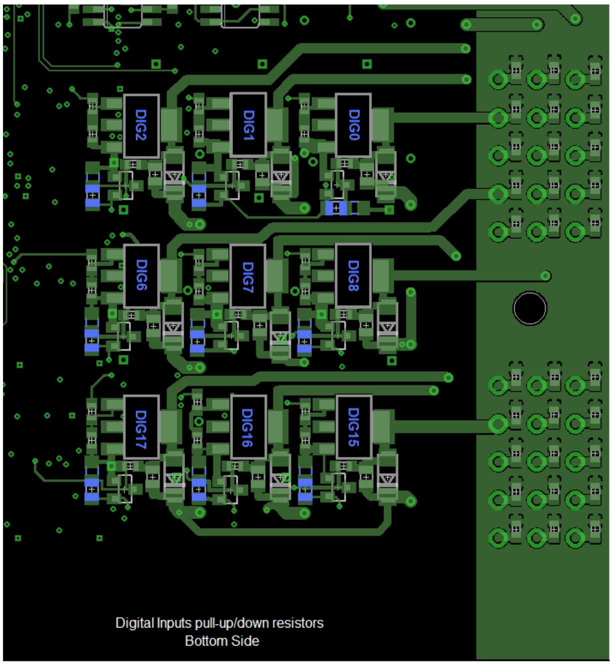
30way Connector Pin	Digital Channel	MPC563 Input
B1	DIG0	TPUA0
B2	DIG 1	TPUA1
B3	DIG 2	TPUA2
C1	DIG 3	TPUA3
C2	DIG 4	TPUA4
C3	DIG 5	TPUA5
D1	DIG 6	TPUA6
D2	DIG 7	TPUA7
D3	DIG 8	TPUA8
E1	DIG 9	TPUA9
E2	DIG 10	TPUA10
E3	DIG 11	TPUA11
F1	DIG 12	TPUA12
F2	DIG 13	TPUA13
F3	DIG 14	TPUA14
G1	DIG 15	TPUA15
G2	DIG 16	TPUB0
G3	DIG 17	TPUB1
H1	DIG 18 / AIN 7	TPUB2
H2	DIG 19 / AIN 6	TPUB3

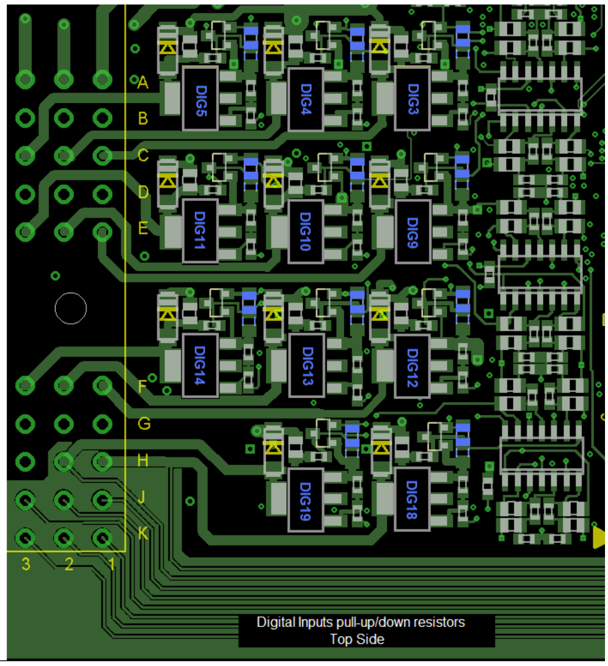
The TPU channels provide many options for processing digital inputs, from simple discrete on or off to frequency measurements and timer capture operations. TPU stands for Time Processor Unit, stand-alone modules within the MPC563 processor. They are further explained in the software guide for the Vega3.

Whilst all of the digital input pins are also connected to the digital outputs as previously explained, pins H1 and H2 of the 30-way connector also double-up as the last two analogue input pins. It is important to check the input signal conditioning circuitry of these analogue inputs will not affect the digital input voltage thresholds (and vice versa when using these pins for analogue inputs).

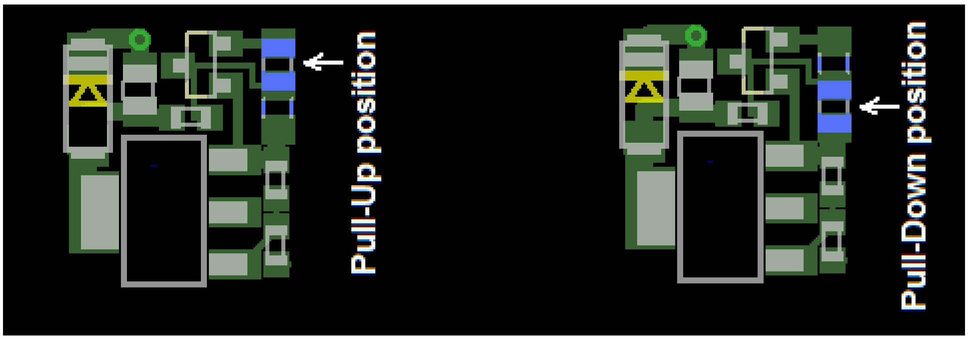
2.9.3 CHANGING DIGITAL INPUT PULL-UPS

The locations of the pull-up resistors are shown below for each of the digital inputs.





By default, all the inputs have resistors fitted as pull-ups. They can be moved to be pull-downs as shown:



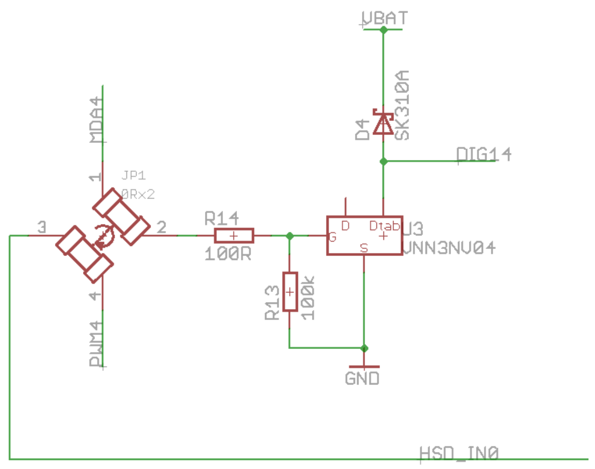
2.10 DIGITAL OUTPUTS

The twenty low-side and four high-side digital outputs are simpler than the digital inputs, having little in the way of configurable hardware. They provide pulse width modulation (PWM) of outputs as well as simple on/off switching.

2.10.1 MPC563 DIGITAL OUTPUTS ASSIGNMENT

Connector Pin (If applicable)	Digital Channel	MPC563 Output	Configuration
30-B1	DIG0	TPUB4	
30-B2	DIG1	TPUB5	
30-B3	DIG2	TPUB6	
30-C1	DIG3	TPUB7	
30-C2	DIG4	TPUB8	
30-C3	DIG5	TPUB9	
30-D1	DIG6	TPUB10	
30-D2	DIG7	TPUB11	
30-D3	DIG8	TPUB12	
30-E1	DIG9	TPUB13	
30-E2	DIG10	MDA0 / PWM0	Move jumper R199 for PWM0
30-E3	DIG11	MDA1 / PWM1	Move jumper R213 for PWM1
30-F1	DIG12	MDA2 / PWM2	Move jumper R192 for PWM2
30-F2	DIG13	MDA3 / PWM3	Move jumper R195 for PWM3
30-F3	DIG14	MDA4 / PWM4	Move jumper JP1 for PWM4*
30-G1	DIG15	MDA5 / PWM5	Move jumper JP3 for PWM5*
30-G2	DIG16	MDA6 / PWM6	Move jumper JP2 for PWM6*
30-G3	DIG17	MDA7 / PWM7	Move jumper JP4 for PWM7*
30-H1	AIN7 / DIG18	MDA8	
30-H2	AIN6 / DIG19	MDA9	

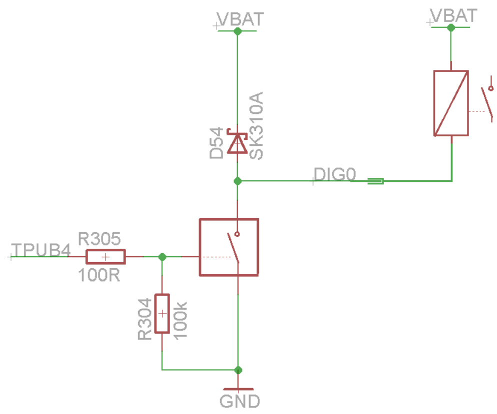
* Jumpers JP1, 2, 3 and 4 are dual jumpers (i.e. DPDT) which also control the High Side Drive control signals, as shown below. This allows the MDA or PWM signal to be used for either outputs.



2.10.2 LOW-SIDE DRIVES

In their simplest form, low-side drives are used to switch electrical loads such as external relays or lamps.

For example, consider digital output 0 (DIG0). By turning on TBUB4 of the processor, the low side switch is energised and the external relay is connected to ground, switching it on. If using the Vega3 blockset, this is simplified further – just select the connector pin to be used from the drop down menu.



All Vega3 low side digital outputs have built-in protection diodes, to prevent inductive loads such as relays damaging the low side switch at switch-off.

The switching MOSFET on each channel is fully protected against over-current, over temperature and short-circuit. It has an $R_{DS(on)}$ of 120mΩ and the device current limits at 3.5A.

The outputs are also able to be PWM controlled via software, allowing brightness control of lamps or speed control of small DC motors. Some outputs (DIG10 to DIG17) may need configuration changes to achieve this, please refer to the table in section 2.10.1.

2.10.1 HIGH SIDE DRIVES

The high side outputs are controlled by the following MPC563 pins:

Connector Pin	Digital Channel	MPC563 Output	Configuration Jumper
18-C2	HSD0	PWM4 / MDA4	JP1 (pair)
30-A3	HSD1	PWM5 / MDA5	JP3 (pair)
30-A2	HSD2	PWM6 / MDA6	JP2 (pair)
30-A1	HSD3	PWM7 / MDA7	JP4 (pair)

The outputs are controlled by a single solid state relay capable of supplying four outputs of 3A. Note that there is a limit of 10A per pin before temperature de-rating (see section 2.2.1), and that this applies to the Vbat input pin from which these high side outputs are supplied.

2.10.2 SENSOR SUPPLY

The 5V output on Pin 18-C3 is switched off by default. It can be switched on with MPIO5, or selecting 5V Sensor supply from the Vega Blockset.

The sensor supply output pin is monitored through a 2:1 voltage divider with ADC9.

This supply output is also used as an alternate reference voltage for the ADCs, i.e. the MPC563 “ALTREF” input.

2.10.3 INTERNAL PERIPHERAL CONTROL

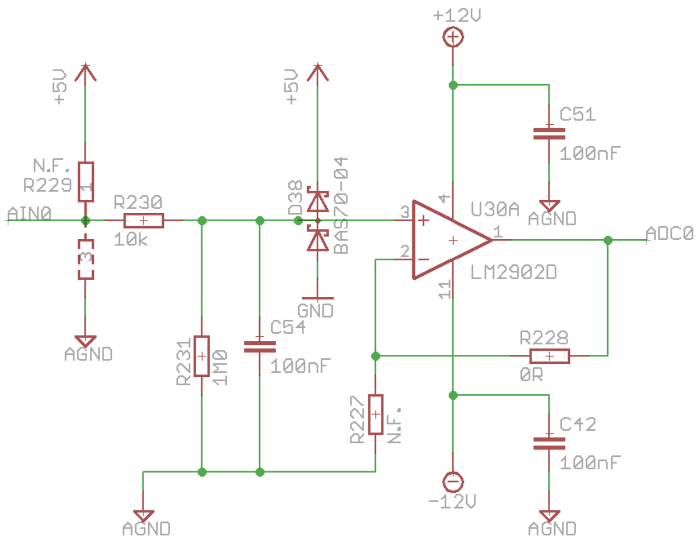
Several MPIO lines control the Vega 3 peripherals.

MPC563 Output	Peripheral	Notes
MPIO1	Hold-On	Holds power on to the Vega3 regardless of KeyOn state.
MPIO1*	LIN	Output Enable. Active high.
MPIO2	LIN	Wake. Active High.
MPIO3	FLASH	R/B Input
MPIO4	RS232	FTDI pin CBUS3
MPIO5	5V Sensor Supply	Output Enable. Active high.
MPIO6	Accelerometer	Self test. Active high.

***** At revision B of the Vega3 PCB, this line is erroneously connected to both the LIN Enable and the Hold-On control line. This line should always be taken low during a controlled shut-down.

2.11 ANALOGUE INPUTS

There are 8 identical analogue input buffer circuits, each as shown below:



The default configuration is as a buffer with a gain of 1. A 10k resistor and 100nF capacitor form a low-pass filter with a cut-off frequency of 160Hz. There is a weak pull-down resistor to discharge the filter capacitor, and a Schottky diode pair clamps any voltage below -0.3V and above 5.3V to the 5V supply rails.

Since the analogue inputs to the MPC563 processor are 0 to 5V the default “unity gain” setting limits the external voltages that can be measured to 5V also.

If a larger voltage needs to be measured, the 1M0 pull-down can be replaced with a lower value to create a potential divider (i.e. replacing 1M0 with 10k0 allows up to 10V to be measured).

Note that this potential divider forms the input resistance of the analogue input, it may be necessary to increase the 10k series resistor to prevent loading of the voltage being measured.

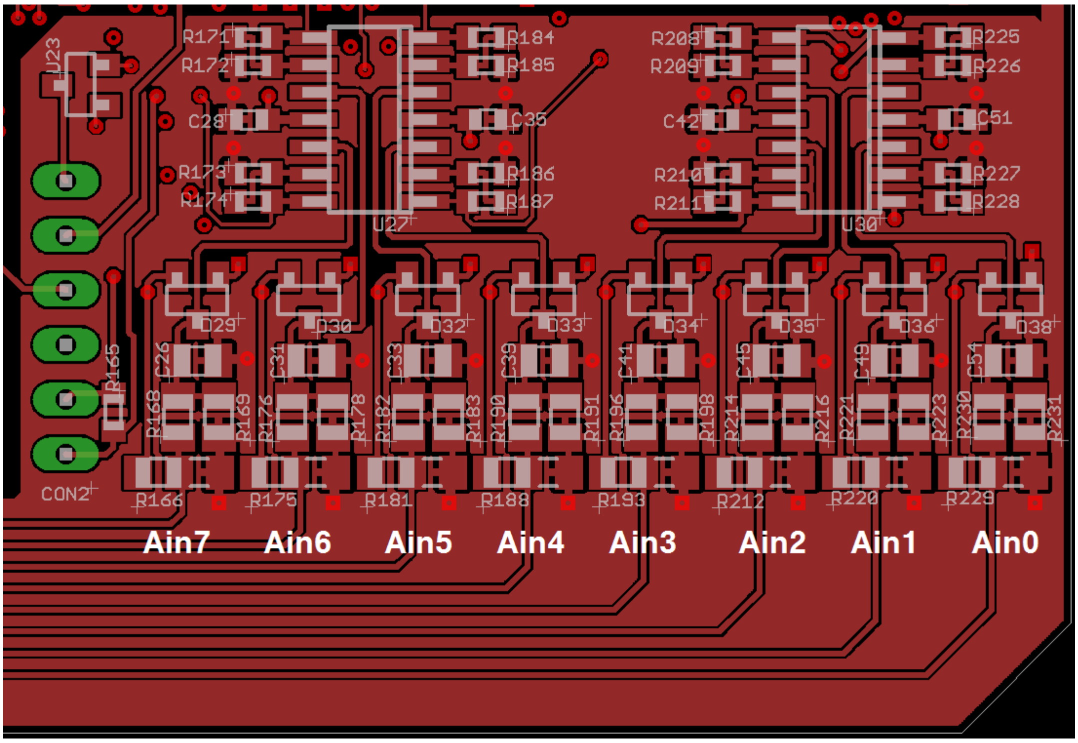
A “not fitted” pull-up at the input pin can be fitted when an external potentiometer to ground is required, effectively supplying the high side of the potentiometer.

Physically, the channels are arranged from right to left on the PCB. Each of the components is clearly marked, and the relative positions are identical from one channel to the next.

Note that the last two channels share a connector pin with digital inputs. Ain6 is connected to Dig19 and Ain7 to Dig18. It is possible to use both simultaneously, but care needs to be taken with pull-up and pull-down resistor configuration to prevent interaction.

From a software perspective the channels are split in half between A_AN0,1,2,3 and A_AN48,49,50,51. See the table in the next section for more information.

2.11.1 PCB LAYOUT OF ANALOGUE INPUTS



2.11.2 INTERNAL ANALOGUE CHANNELS

In addition to the 8 external inputs, there are several analogue inputs that monitor internal voltages, temperatures and acceleration.

VEGA3 Function	VEGA3 Channel Name	MPC563 PIN NAME
External ADC0 to 3	ADC0 to ADC3	A_AN0 - 3
External ADC4 to 7	ADC4 to ADC7	A_AN48 - 51
Vbat Voltage	ADC8	A_AN52
5V Sensor Supply Mon.	ADC9	A_AN53
KeyOn Voltage	ADC10	A_AN54
2V6 Monitor	ADC11	A_AN55
Internal Temperature	ADC12	A_AN56
Accel_X	ADC13	A_AN57
Accel_Y	ADC14	A_AN58
Accel_Z	ADC15	A_AN5

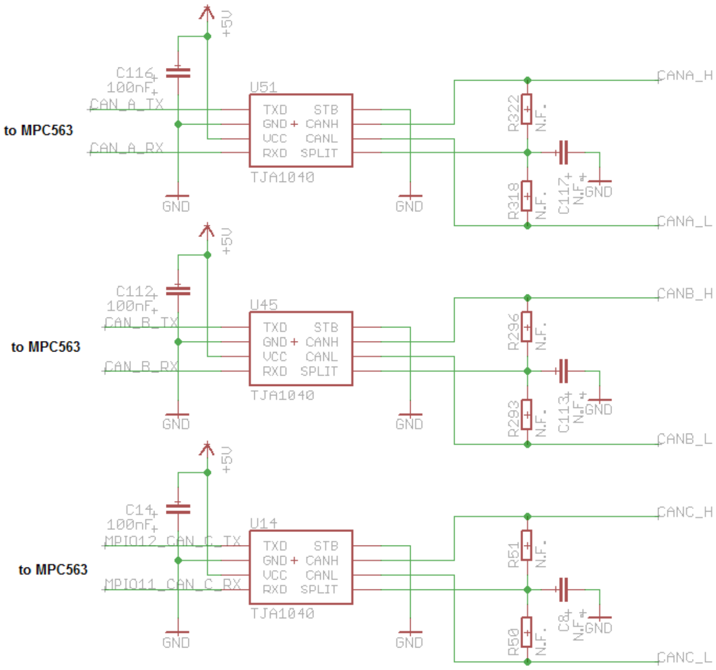
2.11.3 MPC563 DIGITAL OUTPUTS ASSIGNMENT

Connector : Pin	Digital Channel	MPC563 Output	Configuration Jumper
30 : B1	DIG0	TPUB4	
30 : B2	DIG 1	TPUB5	
30 : B3	DIG 2	TPUB6	
30 : C1	DIG 3	TPUB7	
30 : C2	DIG 4	TPUB8	
30 : C3	DIG 5	TPUB9	
30 : D1	DIG 6	TPUB10	
30 : D2	DIG 7	TPUB11	
30 : D3	DIG 8	TPUB12	
30 : E1	DIG 9	TPUB13	
30 : E2	DIG 10	MDA0 / PWM0	R199
30 : E3	DIG 11	MDA1 / PWM1	R213
30 : F1	DIG 12	MDA2 / PWM2	R192
30 : F2	DIG 13	MDA3 / PWM3	R195
30 : F3	DIG 14	MDA4 / PWM4	JP1 (pair)
30 : G1	DIG 15	MDA5 / PWM5	JP3 (pair)
30 : G2	DIG 16	MDA6 / PWM6	JP2 (pair)
30 : G3	DIG 17	MDA7 / PWM7	JP4 (pair)
30 : H1	DIG 18	MDA8	
30 : H2	DIG 19	MDA9	
18 : C2	HSD0	PWM4 / MDA4	JP1 (pair)
30 : A3	HSD1	PWM5 / MDA5	JP3 (pair)
30 : A2	HSD2	PWM6 / MDA6	JP2 (pair)
30 : A1	HSD3	PWM7 / MDA7	JP4 (pair)

2.12 CAN INTERFACES

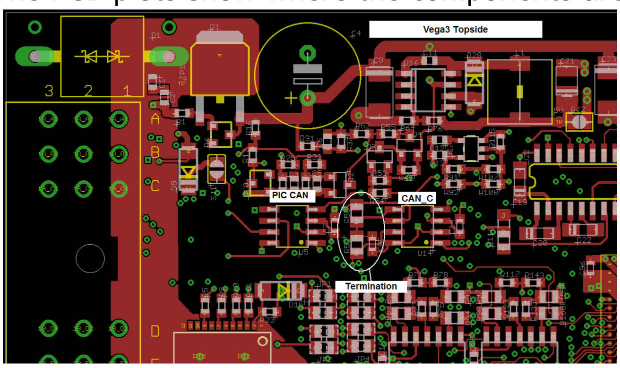
Termination
Every CAN bus requires a 120R termination resistor at each end of the CAN bus pair.
Due to the many places the termination resistors can be fitted, the default configuration of the Vega3 is to have empty pads where termination resistors can be added.

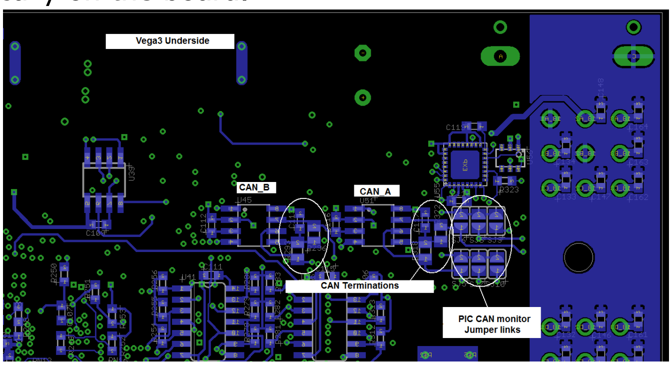
This schematic shows the termination configuration of the three main CAN buses.



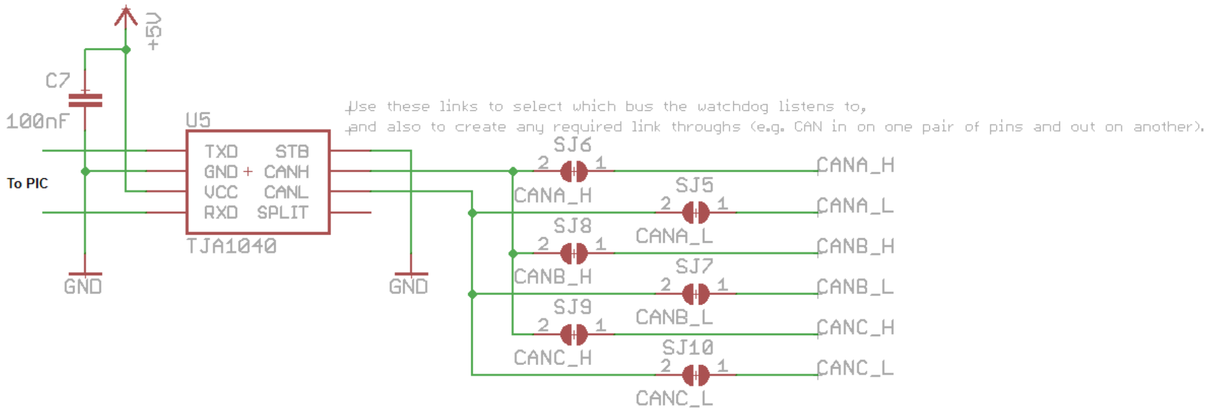
It shows two 60R resistors in series with an optional 10nF capacitor from the centre point to ground.
The resistors are 0805 components so they're easy to solder.

The PCB plots show where the components are physically on the board.





The second processor, the PIC, can also be connected any of the three main CAN buses by shorting the appropriate jumper pair. This is shown below.



These jumpers also allow hardware loopback of one CAN bus to another. You could link CAN_A to CAN_C for instance, allowing physical connection of two buses at the Vega3 connector rather than harness splices.

2.13 USB INTERFACES

The MPC365 USB interface is implemented with an FTDI USB to serial IC, connected to the MPC563 with TXD1 and RXD1. Serial data transmitted by the connected host will appear at the MPC563 as if it were connected via RS232.

The PIC32 USB interface is a true USB port, configured as a device, connected directly to the processor.

2.14 RS232 / LIN INTERFACE

Both the RS232 port and the LIN interface use the same TXD2 & RXD2 pins of the MPC563.

The RS232 receive pin is directly connected to pin 18-F2, but the RS232 transmit pin and the LIN line share pin 18-F1.

By default the RS232 TX is connected to the pin and the LIN bus is not. Move jumper R116 to select the LIN interface.

Frequently Asked Questions

Q) With a low side drive off, I still get 7V across my load. With the low side drive on, I get the full 12V. Why?

A) The low side drive outputs pins are shared with the digital inputs. The digital inputs have 10k pull-up resistors fitted as default between the input and the internal 5V supply. If the load is very light (a single LED, or no load at all for example) then the 7V you see is the difference between your 12V external supply and the 5V internal supply.

Solution: For a relay coil or a lamp this will present no problem as the load impedance is much lower than the 10k pull-up. For light loads, remove the 10k pull-up from the shared digital input altogether. If you absolutely need both, consider connecting your load between a 5V supply and the low side drive rather than from 12V.

Q) Why do the outputs briefly pulse on during power up?
A) Because the processor has internal pull-ups and pull-downs that are invoked during reset. Check that the PULL_SEL resistor (R239) on the underside of the board is in its pull-down configuration (i.e. pin R26 of the processor is connected to ground) to prevent this.